Introducing an Auxiliary Accumulator with Pre-Charged Oil to Air Conditioning System

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ABSTRACT

The rotary compressor accumulator with pre-charged oil has already been developed and the concept published.[1] Compared to the conventional accumulator, the new accumulator differentiates itself from the conventional one in that the new accumulator is pre-charged with a pre-determined amount of oil. It offers advantages as a conventional accumulator attached to rotary compressor. This paper now examines potential advantages of using the new accumulator as an auxiliary system component of air conditioning system, not as an accumulator attached to compressor. Advantages of such an auxiliary device are demonstrated in an actual air conditioning system with a special attention to oil and refrigerant management.

INTRODUCTION

The primary function of an accumulator in rotary compressor is to control excess liquid refrigerant. However, the size given may not be able to digest the actual excessive refrigerant charge in the system to protect compressor. Thus, an auxiliary liquid control device such as auxiliary accumulator is sometimes installed between rotary compressor and evaporator. If the auxiliary accumulator is partially pre-charged with oil it can be quite effective in improving the quality of oil. As liquid refrigerant enters the device, it mixes first with oil in the device and improves the quality of oil/refrigerant mixture before entering conventional suction accumulator of rotary compressor. This auxiliary accumulator (Fig. 1) is used in addition to a conventional accumulator attached to rotary compressor. The auxiliary accumulator is to offer additional oil supply to compressor as well as controlling the excess refrigerant.

THE PROPOSED CONCEPT

Conventional accumulators are in general all similar (Fig. 2), but the accumulator with pre-charged oil differentiates from the conventional accumulators in that the auxiliary accumulator is pre-charged with oil to the orifice level. This pre-charged oil amount is in addition to the amount of oil normally charged into compressor oil sump, and makes the total amount of oil charge greater. This increased oil helps improve compressor lubrication under boundary lubrication condition due to liquid refrigerant. Without increasing oil amount in oil sump, the quality of the oil is improved with an auxiliary accumulator with pre-charged oil. That is, additional oil is charged into the auxiliary accumulator, and oil return orifice is so located in elevation that a specified volume is contained below the orifice. Though the pre-charged oil may partially leave the accumulator when liquid refrigerant contained in the auxiliary accumulator raises level of liquid phase above the orifice on standpipe, the pre-charged oil is mainly contained in the accumulator. This type of accumulator (Fig. 1) offers two significant advantages under flood-back condition of liquid refrigerant. The liquid refrigerant flowing into the accumulator first mixes with oil contained in the auxiliary accumulator prior to flowing into the compressor. This mixing of liquid refrigerant and oil improves the quality (oil/refrigerant ratio) prior to entering the compressor. Additionally, the amount of oil pre-charged increases the total amount of oil in the system without the necessity of making the oil sump larger.

EFFECTS OF THE AUXILIARY ACCUMULATOR

In general, the quality of the suction flow entering the compressor accumulator (CA) is relatively more oil-rich, when an auxiliary accumulator (XA) is installed.

Dry Suction - When the flow to XA inlet is superheated liquid-phase refrigerant accumulates neither in the CA nor the XA. In this case, the XA acts as an oil reservoir.

Wet Suction - As flow superheat is decreased more liquid droplets are present in the stream and the quality of the flow becomes "wet." The relatively small amount of liquid mixes with oil in the reservoir(XA), and makes the flow quality more oil rich compared to the case of without XA.

Liquid Flood-back - As an another extreme condition, now liquid-phase refrigerant rushes into the XA. A shot of in-rush liquid refrigerant, like following defrost cycle, mixes with the oil in the XA prior to entering the CA. The flow out of XA provides better quality oil/refrigerant mixture to CA. The liquid-phase level of the reservoir is raised.

OPERATING CHARACTERISTICS AND INHERENT ADVANTAGES

The concept offers substantial advantages in dealing with excess refrigerant and liquid flood-back. Compressor in the unit equipped with a XA is expected to last longer in life under severe suction flood back and transient liquid flood-back conditions. The following lists several operating characteristics observed and inherent advantages of the new concept:

1. The auxiliary accumulator, XA, seldom allows the slug of liquid to go directly into compression chamber of the compressor. The reason is that any slug of liquid first mixes with oil in XA, thus it is no longer act as a true slug of liquid when it reaches to the suction accumulator of the compressor.

2. As liquid refrigerant mixes with oil, the resultant liquid/oil mixture is now less damaging to compressor lubrication compared to the case where slug of liquid is directly drawn into the CA, then into compression chamber. In reality, the XA acts as a "shock absorber."

3. In the event that a slug of liquid momentarily displace oil in the XA, oil does eventually return to the reservoir at the original level.

4. The oil stored initially in the XA improves the oil/refrigerant ratio. This is true even the additional oil is located in remote location separately from the compressor oil sump. The XA contains some refrigerant and additional oil will be drawn into the compressor.

5. In a steady state operating condition, oil-rich liquid level in XA stays at the level of the orifice elevation. Any excess liquid refrigerant/oil is passed to the CA through the orifice.

6. Normally increasing the size of compressor oil sump is a capital-intensive and it may even not feasible due to complexity in manufacturing. In this kind of situation, the concept offers a practical and effective alternative to increasing the oil sump.

TEST SET-UP AND PROCEDURES

Set-up of the Test Unit - The test unit is two-evaporator 12K Btuh [3.5 KW] unit. The system was set up such a way that an auxiliary accumulator could be tested either in system or out of it (Fig. 3). The standard system charge is 1000 g. Initial amount of oil charge to compressor is 550 cc, while the auxiliary accumulator has capacity of 400 cc below the orifice on the standpipe and overall effective volume of 700 cc. Unit was located in 32C ambient room and this simulates a high load condition. Only one fan coil unit (evaporator) was on, and the other inactivated to simulate suction flooding condition.

Test Procedure (Fig. 3) - Prior to any test, the exit valve[a] was left open while the inlet[b] closed off auxiliary accumulator, XA. This is to boil off the refrigerant remained in the auxiliary accumulator and the outlet valve[a] was closed off later to isolate the XA in the circuit. Then, the test with the XA out of the flow circuit was run. Subsequently, the valves [a] and [b] were open and valve[c] closed to bring the XA into the circuit. In order to keep the XA out of the circuit, valves [a] and [b] are closed while the valve[c] is opened.

Test Data - A total eight(8) test runs was conducted with different degree of refrigerant charge, oil charge amount in the auxiliary as well as in compressor oil sump (Table 1 /Section A). From the operating data (Table 1 /Section B) of the unit, calculated data (Table 1 /Section C) are listed for analysis.

Observation Through Sight Glasses - Throughout of the whole series of the testing, sight glasses installed at compressor, CA and XA were recorded on videotape. It is clearly shown that the compressor oil sump becomes very active and suction accumulator becomes filled up to different degrees with liquid refrigerant. As system refrigerant charge is increased, suction accumulator accumulates more liquid, and this is as expected. In the meantime, more liquid backs up, more so as the system refrigerant is increased. In the test where the compressor is undercharged in the oil sump and the XA is charged with 400 cc oil (up to the orifice elevation), the oil/refrigerant level is increased while the XA contained oil and liquid refrigerant.

TEST RESULTS

Bottom Shell Superheat - In every group case, a substantial improvement is seen by using the XA and the improvement is more pronounced as the system is further over-charged. This effect is seen in Fig. 4. Improvement in bottom shell temperature ranges from 10 C (100% system charge) to 20 C (200% charge).

Top Shell Superheat - The effect of having the XA is also pronounced when the top shell superheat is compared (Fig. 5). The superheat difference ranges from 10~15 C (100% - 150% R22 charge) to 20 C (200% R22 charge).

Percent of Refrigerant in Compressor Oil Sump - Percent of refrigerant increases with increase of system refrigerant as expected (Fig. 6). When the XA is brought into the system circuit, the superheat is always higher than that of without the XA; 35% - 50.2% - 99.9% drops to 27.3% - 31.7% - 41.9% for

100% - 150% - 200% of the standard refrigerant charge respectively. The auxiliary accumulator becomes more effective as system refrigerant is increased in greater percentage of the standard charge.

Oil Viscosity - Ultimately, viscosity of oil must be improved to help bearings improve their life. The auxiliary accumulator is effective in this regard and the effectiveness increases with higher refrigerant charge (Fig. 7). Viscosity of oil 1.54 - 0.80 – 0.0 cSt increases to 2.0 –1.72 – 1.18 cSt for 100% - 150% - 200% of the standard refrigerant charge respectively. This is quite significant in that the compressor will not survive at 150% or higher refrigerant while system with XA will have a better chance of surviving even at the system charge.

Effect of Initial Oil Charge in Auxiliary Accumulator (Table 1) - The test group I, II, and III had initial oil charge of 200 cc in XA and standard compressor oil charge of 550 cc in the oil sump. The test group IV had initial oil charge of 400 cc in XA and 300 cc in the oil sump. The oil charge of 400 cc brings up the oil level in the XA to orifice on the standpipe and this is the standard oil charge volume in the XA. Overall, the test groups I, II and III had a total of 750 cc oil charge in the system, while the group IV had 700 cc oil.

Test group IV also shows improvements in all categories (superheat of top shell, bottom shell, percent of R22 in oil sump and oil viscosity) discussed in the above, but the differences are smaller. This is due to the fact the initial oil charge in the oil sump is less, only 55% of the standard.

Low Oil Level in Oil Sump - Oil level in compressor is lowered when compressor is installed in a unit and some oil is used in wetting the system components such as heat exchanger, motor inside compressor and interconnecting tube line. Benefits of the XA are self evident in improving flooding situation and all parameters that are discussed in the previous sections.

SUMMARY and CONCLUSIONS

Based on the extensive development works of the compressor with pre-oil charged accumulator, adding a stand-alone auxiliary accumulator that is pre-charged with oil between compressor and evaporator offers many advantages. Benefits of such system have been experimentally observed and verified. The accumulator of pre-charged oil that can be used in place of conventional suction accumulator has now been applied as a system auxiliary accumulator. Parameters that are related to lubrication aspects show substantial improvements over a system without the auxiliary accumulator. The auxiliary accumulator is more effective with (1) increasing refrigerant charge, and (2) low oil charge in the oil sump.

REFERENCE

1. Yun, K. W., *"Compressor Suction Accumulator with Pre-Charged Oil."* Proceedings of the International Compressor Engineering Conference at Purdue, July 14-17, 1998.

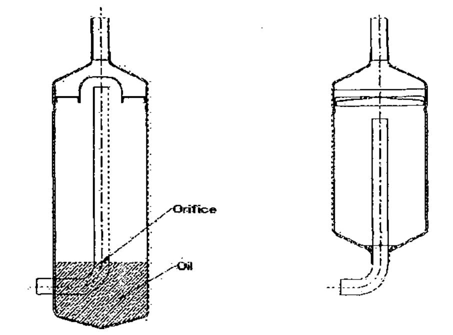

Fig.1 The Proposed Accumulator   Fig.2 Conventional Accumulator

Fig. 3 The Test Unit Set-

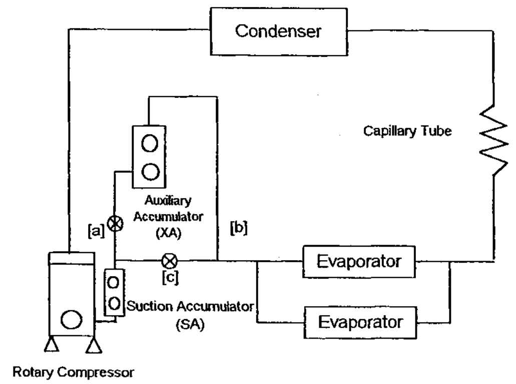

Fig. 4 Bottom Shell Superheat

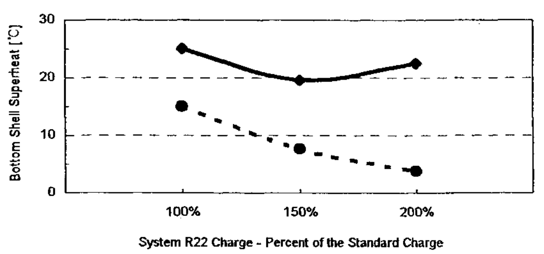

Fig. 5 Top Shell Superheat

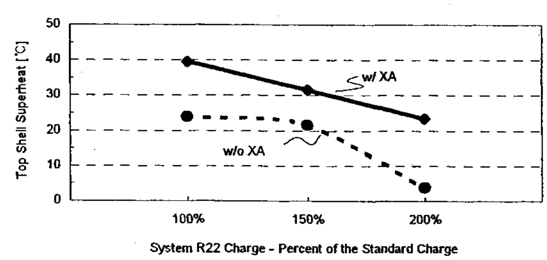

Fig. 6 Percent of R22 in Compressor Oil Sump

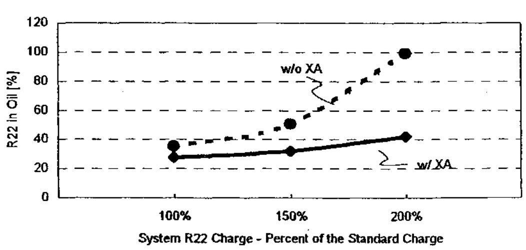

Fig. 7 Viscosity of Oil in Compressor Oil Sump

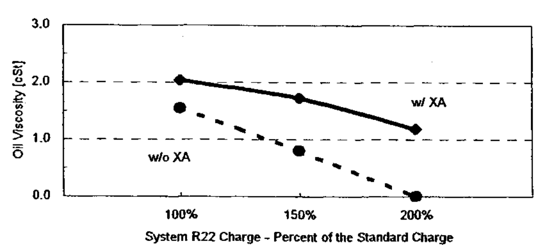

Table 1 SET-UP and DATA OF TESTS WITH & WITHOUT AUXILIARY ACCUMULATOR

Section A		Test Group	I		II		III		IV	
		Circuit	CA	XA	CA	XA	CA	XA	CA	XA
		Aux, Accum in Circuit	No	Yes	No	Yes	No	Yes	No	Yes
		System Charge	1000 gr	1000 gr	1500 gr	1500 gr	2000 gr	2000 gr	1500 gr	1500 gr
		Compr. Oil Charge	550 cc	550 cc	550 cc	550 cc	550 cc	550 cc	300 cc	300 cc
	TC#	Oil Charge in Aux. Accum	200 cc	200 cc	200 cc	200 cc	200 cc	200 cc	400 cc	400 cc
Section B	51	Condenser Out	48.0	48.0	49.3	48.8	45.9	46.2	42.7	41.3
	52	Condenser In	42.0	43.0	42.5	42.3	37.2	39.7	49.0	47.9
	50	Liquid Temp	42.0	43.0	42.3	42.8	37.4	40.0	43.6	42.0
	49	Evaporator In	7.5	6.5	7.9	7.8	10.1	6.3	8.2	7.5
	48	Evaporator Mid	8.5	8.0	9.0	9.3	12.0	7.7	9.6	9.0
	47	Evaporator Out	4.5	4.0	4.8	5.0	11.1	3.4	5.2	5.0
	46	Aux Accaum In	42.0	43.0	34.9	-0.9	30.0	-2.4	37.9	0.8
	45	At Orifice (Shell)	36.0	3.0	34.1	0.8	27.6	-0.8	38.0	1.5
	44	SuctionTemp	-2.0	7.0	-1.8	-0.1	0.4	-3.0	-0.5	6.1
	43	Standpipe Outlet	7.5	18.5	5.0	6.7	4.6	2.2	0.8	4.5
	42	Bottom Shell	67.0	76.5	60.7	72.6	49.9	62.9	67.0	74.8
	41	Top Shell	76.0	91.0	74.5	84.6	55.8	75.4	78.0	84.4
	9	Ambient	32.0	33.0	33.8	35.0	34.7	33.6	34.9	33.9
		Suction Pressure	3.8	3.7	4.3	4.3	4.0	4.0	4.0	4.0
		Discharge Pressure	19.7	19.4	20.3	20.3	19.8	19.8	19.8	19.8
Section C		Sat. Evap. Temp	-1.0	-2.0	2.0	2.0	0.0	0.0	0.0	0.0
		Sat. Cond. Pressure	52.0	51.5	53.0	53.0	52.0	52.0	52.0	52.0
		Discharge Pressure, psia	294.8	290.6	303.4	303.4	296.3	296.3	296.3	296.3
		Degree of Subcool	10.0	8.5	10.7	10.2	14.6	12.0	8.4	10.0
		Suction Superheat	-1.0	1.0	-3.8	-2.1	0.4	-3.0	-0.5	6.1
		Bottom Shell SH	15.0	25.0	7.7	19.6	3.8	23.4	15.0	22.8
		Aux Accum In - Suction	44.0	36.0	36.7	-0.8	29.6	0.6	38.4	-5.3
		Standpipe Out - Suction	9.5	11.5	6.8	6.8	4.2	5.2	1.3	-1.6
		Temp Rise in Evap	3.0	2.5	3.1	2.8	-1.0	2.9	3.0	2.5
		Top Shell - Bottom Shell	11.0	14.5	13.8	12.0	5.9	12.5	11.0	9.6
		Aux Accum In - Out	34.5	24.5	29.9	-7.6	25.4	-4.6	37.1	-3.7
		Top Shell SH	24.0	39.5	21.5	31.6	3.8	23.4	26.0	32.4
		R22 in Oil Sump (%)	35.5	27.3	50.2	31.7	99.9	41.9	35.9	29.1
		Oil Viscosity (cSt)	1.542	2.032	0.803	1.720	0.000	1.178	1.516	1.906